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(71) Applicant
BCIRA (United Kingdom),
Alvechurch, Birmingham B48 7QB

(72) Inventor
William McCormack

(74) Agent and/or Address for Service
Barker Brettell & Duncan,
138 Hagley Road, Edgbaston, Birmingham B16 9PW

(54) Article recognition and handling system

(57) A succession of articles e.g. casting to be fettled, presented at random and of random orientation is identified in turn and orientated to a predetermined configuration by a system which not only obtains an image in the form of a silhouette from which are derived a number of dimensional parameters which are compared in a computer with the stored parameters from known classes of article but also a weight parameter is included. The articles may be turned over from one stable position of repose to another for identification and/or for final positioning by pushing them over a stop 10 onto a adjustable height platform 4.

Robot 11 may then remove correctly orientated and identified articles for appropriate treatment as required for each class of article.

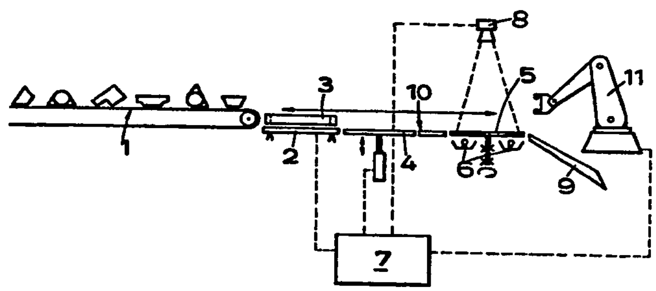

FIG.1.

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The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

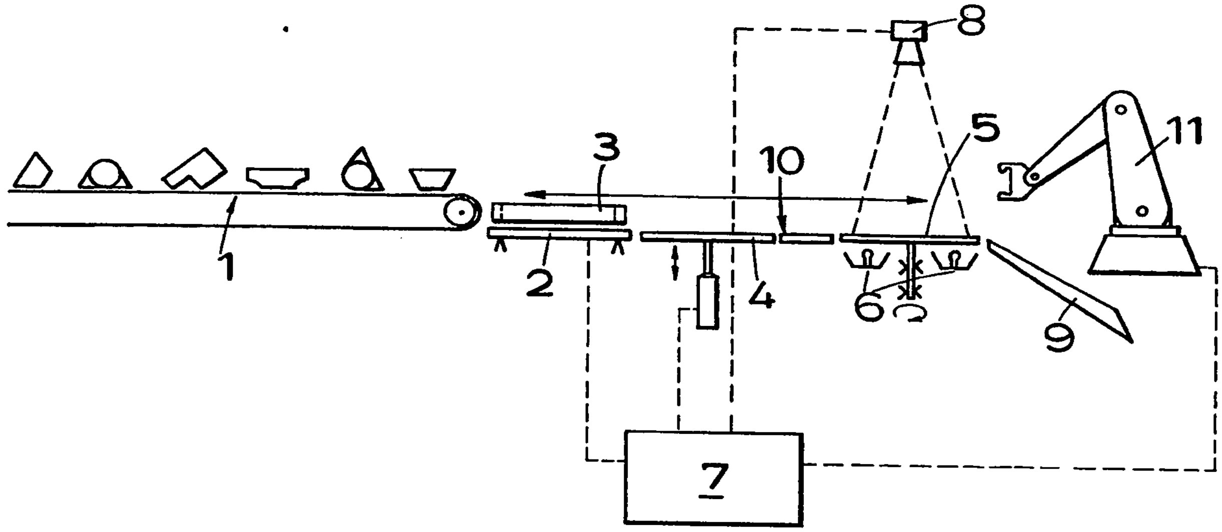

FIG.1.

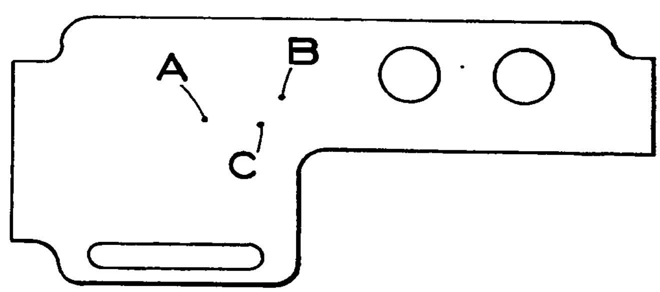

FIG.2.

SPECIFICATION

Article recognition and handling system

This invention relates to a system designed to transfer, by a series of inspections and manipulations, a random order and arrangement of different finished or unfinished articles of varying shape to a state where they are each identified and in a known and predetermined position and orientation for subsequent automatic handling and/or treatment.

Pattern recognition systems have been the subject of much discussion and development in recent years, and the general line of development has been in the direction of illuminating the object to be identified and scanning it optically to compare it with images of known articles. Such a system depends on the article being of a known exact shape, and also assumes the possibility of obtaining good optical contrast to define clearly the outline of the article. The use of grey-level cameras to obtain the image, with automatic adjustment of the contrast to suit the conditions, is known and goes some way to deal with the second of these problems, but not the first. Difficulties arise when the articles to be identified in a defined class are expected in practice to have a significant degree of variation in shape yet still be acceptable despite such variations, provided they are, for example, variations in certain dimensions or profiles but not in others.

A further limitation on most known systems is that they assume the articles are lying flat in a predetermined plane.

One field where the problem exists of acceptable articles having a substantial degree of variation in shape is that of identifying castings, mouldings or forgings, on which unwanted material is present, for example in the form of flash, feeder stubs and risers. For example the flash extending laterally at the parting plane may extend sufficiently far in various random directions to alter significantly the silhouette of the article when viewed in a direction perpendicular to that plane and in the known systems it could lead to the rejection of a perfectly acceptable article. This variation of physical parameters can cause confusion and wrong decisions. Yet there is a need in particular to be able to identify the handle such articles reliably, for example, in equipment for feeding them to a subsequent fettling, flash-removal or other finishing process.

At the same time, in the case of castings, there is a need to reject reliably mis-run castings, castings with no cord cavity, or components with so much excess material that they would be difficult to manipulate in the subsequent operations, or even might damage the tools used in such treatment.

The aim of this invention is therefore to provide a way of identifying articles by type on the basis of particular articles of ideal form and despite some degree of variation in the observable parameters, so that it should not be wrongly rejected as deficient when the variation is in a parameter that is not vital to the essential character or quality of the article, and also a way of then positioning and orientating the object into a predetermined known attitude for further handling or treatment.

A further aim is to provide such a system which is at the same time sufficiently flexible to be adapted as required to handle entirely new classes of articles, i.e. to be 'taught' fresh recognition skills.

According to the invention we now propose a system for identifying and positioning different articles fed to it at random comprising a pattern recognition system involving an illumination system using radiation which is not necessarily visible light indeed not necessarily electromagnetic and a profile or silhouette detector, in combination with a computer to which signals representing the weight as well the profile parameters are fed, the computer being arranged to select the minimum number of such parameter signals that is found to be necessary to identify reliably the class to which the article belongs, with means for rejecting those not so identified and means for turning to a predetermined attitude those which are accepted.

The system involves means for re-positioning the article where it is not identified first time around and according to a further feature of the invention the re-positioning means may include a step device that causes the article to be tilted to a fresh stable position under its own weight, possibly two or three times.

Preferably the article is also weighed and the weight forms one of the parameters fed to the computer.

The articles which are recognised are passed to the re-positioning means where their orientation is adjusted by rotation, horizontal displacement, and possibly tilting to a new stable rest position by the step device mentioned above. The step can be of adjustable height, its height being set in accordance with the article identified, and attitude which it is then occupying.

The article can be returned to the recognition or identifying means after each mechanical operation or series of operations to be rechecked only up to a certain specified maximum number of returns, and is rejected altogether if it has not achieved the correct position for subsequent pick-up or final adjustment within this predetermined number of movements. The article may then be acted upon by final positioning or pick-up means at which point it is in exactly the required configuration from which the computer may initiate a further sequence of treatment or handling, such as, fettling, machining, painting, welding, assembly, inspection or any other process. This

is in contrast to some known systems, in which the recognition system, having identified this article, then has to instruct a robot or other handling device how to pick it up from the random position in which it has been identified as lying, and the recognition system is therefore in practice only usable with a particular associated robot system.

Furthermore, because the computer has identified the article, it is able to initiate those further operations in the appropriate manner, i.e. to instruct a robot or machining system to select the appropriate stored program, starting with selecting the appropriate movements for a gripper or other transfer system for picking the article up from the position into which it has been brought by the system which is the subject of the invention, and removing it for the further handling.

The identification or recognition of the article is achieved by comparison with a predetermined set of reference parameters, including the weight, and these are evaluated from acceptable articles and 'taught' to the control means. The number of parameters used, which, besides the weight could include the area of the silhouette, its perimeter and others, are selected to be the minimum necessary to identify the article unambiguously as belonging to a particular class.

It is also important that the system should, by the parameters used, be able to distinguish uniquely all the stable positions of each article taught, including its angle of rotation when placed in the viewing position, and be able, with a high degree of reliability, to reject articles not recognised. The necessary parameters may be selected entirely by the computer or may be wholly or partially selected manually on the basis of previous operating experience with the articles to be recognised. This number is found by the computer taking a large selection of parameters during its 'teach' mode and eliminating those which are not necessary for a definite identification; the remainder are then those chosen to be employed during operation of the system.

This method allows further classes of articles to be accommodated easily, and the variation in the amount of unwanted material, e.g. in the form of flash on cast, forged or moulded articles, which is permissible is also determined on articles which have material to an acceptable degree. There could be a manual override to alter the acceptable limits of variation of a given parameter if desired; each article has this evaluation of parameters and acceptable limits of variation for every stable position of repose.

The invention will now be further described by way of example with reference to the accompanying drawings, which illustrate a system according to the invention in purely diagrammatic terms, and in which:—

Figure 1 is a side elevation of the system, and

Figure 2 is an outline which is of assistance in understanding the principles by which an article is identified.

There is shown at 1 a belt conveyor carrying a succession of articles of different classes and furthermore articles of a given class will be in different orientations, not only facing in different directions in the horizontal plane but also lying in different attitudes, for example some on their faces and some on their backs or sides. They may, by way of example, be castings emerging from the knock-out station of a foundry and needing now to be fettled; they may or may not still have feeder stubs, but will certainly have some degree of flash, in a form which varies in a random manner.

The purpose of the system according to the invention is to identify those articles and then turn them to a predetermined attitude and orientation for subsequent handling, whilst rejecting articles which are outside acceptable limits, or faulty, or which should not be on the conveyor at all.

First the articles are spaced out on the conveyor 1 so that there are in line with an interval between each adjacent pair, this is a known technique and need not be described. The conveyor feeds the castings singly on demand onto a weighing table 2 supported on load cells (not shown) to produce an electrical weight signal. A photo-cell (not shown) detects the casting as it falls off the conveyor onto the table and automatically stops the conveyor. To avoid damage to the delicate weighing equipment by the impact of the casting on the table, the table is temporarily automatically raised off the weighing equipment by inflatable flexible tubes or bags (not shown) when the conveyor is running and then the tubes are deflated when the conveyor stops.

Lying over the weighing table 2 is an open rectangular frame 3 which carries means for centralising the casting comprising pairs of bars (not shown) which move in from opposite sides and push the casting, regardless of its shape, size, and attitude, to the centre of the table. The frame is, after the weighing operation, translated horizontally, moving the casting with it, across a platform 4, to be referred to later, onto the identification table, shown at 5. This table 5 is translucent and is illuminated from below by a source 6. Furthermore it is rotatable about a central vertical axis with a fine degree of precision under the control of a computer 7.

Above the table 5 is a digital camera 8 which receives a silhouette image of the casting lying centrally on the table (the centralising bars in the frame 3 having been retracted in the meantime).

The source 6 need not be of visible light but on the contrary could use a form of radiation less liable to be affected by the presence

of dirt on the table 5 or in the atmosphere, for example infra-red or ultra-violet light.

The signal produced by the camera 8 is at a single level in binary form, as opposed to a grey-level picture. The digital information which this represents is fed to the computer 7 and compared with that stored from the earlier 'teaching' of the computer by means of standard articles. This teaching will be described in a little more detail below. The signal from the weighing table 2 is also fed to the computer.

The system could, within the scope of the invention, include a second illuminating source and screen, for example looking horizontally, or even a mechanical feeler to sense the attitude, orientation or position of the component in the unlikely event that one device does not discriminate absolutely.

The computer 7 determines whether the information on the weight and shape indicates that the article falls within one of the classes it recognises. As explained above, with articles like castings they may, dependent on their shape, be capable of arriving at the table in any one of three or even more different possible attitudes, each of them a stable position in which it may happen to lie. The computer has recorded in its memory, parameters of each article in every one of its possible stable positions of repose; the means of acquiring such information will be discussed later below.

If the computer fails to recognise the article as falling within any of the classes it has been programmed to accept, then the article is rejected. This can be done in various ways; in the example illustrated the frame 3 is lifted and a ram (not shown) pushes the rejected article down a chute 9. Those articles which are rejected can be inspected visually at leisure to determine whether they are fundamentally faulty or capable of reclamation.

The weight test is a valuable one, particularly in the case of unfinished metal castings. A lower limit can be determined closely for a given casting, representing the article with virtually no flash; if it is below that, then, assuming the casting has been identified through the other parameters as being of a certain class, it must be a mis-run. The upper limit on weight is determined by the maximum acceptable amount of flash. Over this indicates that there is more flash than the subsequent treatment can satisfactorily remove, or that there was a core missing in the mould in which it was cast.

Articles which are recognised have to be re-orientated and/or turned over until they are in the configuration recognised by the computer 7 as correct for the subsequent handling and treatment. Re-orientation in the horizontal plane is easily achieved by rotation of the table 5. To turn the article over into a different stable position of repose we make use of a step, indicated at 10 in Fig. 1. For example, if the computer has ascertained that the article is on its side and needs to be tipped onto its base it is rotated on the table 5 until its base is towards the step 10. Then the height of the platform 4 mentioned earlier, beyond and below the level of the step 10, is adjusted to suit the particular tilting operation to be performed, knowing the class of article and its orientation. The frame 3 then moves to carry the article over the step, so that it falls onto its base on the platform 4, which then rises to lie flush with the step 10, whereupon the frame 3 moves the article, now standing on its base, back onto the table 5.

This tipping operation can, if necessary be repeated more than once to get the article the required way up; it is then turned to the final required orientation. A final check by means of the digital camera 8 ensures that the attitude and orientation are correct, and then the computer can signal that the job of the recognition system is complete, and at the same time it informs the equipment controlling the further treatment what class of article is present. This allows, for example a robot 11 that forms part of that equipment to pick up the article from the table in the correct way and carry it away for that further treatment, for example by hodling it for engagement by fettling grinders. Those grinders will have been programmed in a known manner to engage the article in the appropriate manner, knowing the class of article and the areas in which flash is to be expected.

A limit is placed on the number of manipulations of position or times which an article may be turned over before the component may be accepted, this limit being the maximum number of operations needed to get a component of the type originally identified by the computer from any stable position to the required stable position, and this number can vary with category of article. It is necessary to remove those articles which are likely to damage the tools, machinery or equipment used in subsequent stages of processing, testing or manufacture by virtue of there being too much unwanted material on unfinished articles or by the deformed nature of the article itself.

In a modification of the system described the weighing step could be incorporated in the table 5, eliminating the need for the separate weighing table 2.

We shall now go into more detail about how the computer 7 identifies the class of article from a minimum number of measured parameters.

The computer needs to be informed of the various categories of article which it is required to identify and position and is equipped with a 'teach' mode in which this may be accomplished. A particular article is positioned such that the camera may view its silhouette and feed information to the computer, this be-

ing done for every stable position of repose of the article. To allow for variations in shape of unfinished articles due to flash or other excess material which may later be removed the computer also has presented to it, in all allowable configurations, articles with unwanted material present within limits deemed to be acceptable for subsequent operations and a record of the limits of variations of parameters is made.

In a typical case of a teaching operation a sample of the article is placed on the table 5 and its image analysed in each of twelve different angular positions. The minimum values of certain significant dimensions are recorded. This is repeated for each of several samples of the same class of article and a picture is built up of the maximum and minimum values to be expected for each of those dimensions. Provided the samples are representative of the range of acceptable articles within the class, the maximum and minimum will then cover all the articles which are to be recognised as such. For example in the case of castings some may have very little flash and some may have a lot, some may have flash in one area and some in another. If necessary a manual entry may be made to expand the upper or lower limit of certain dimensions to deal with particular situations.

The teaching process must be repeated for each of the three or more possible positions of response in which the article is capable of lying on the table 5.

It is important to appreciate that, for the recognition step, the computer 7 does not simply look at the image presented to the camera and compare that with a large number of stored images; to do that would require a very large amount of memory to hold the enormous number of images, each of the article in a slight different orientation. Moreover the comparison step would take an unacceptably long time. A further problem is that a casting with an appreciable amount of flash in certain areas might find itself unjustifiably rejected by such a straight comparison method.

Instead the computer derives from the dimensions and other features of the image certain parameters and it is possible to ascertain that, provided the right selection of parameters is made, the combination of them is unique to the given class of article. For example it is relatively easy to derive the parameter and area of the image and the number of holes in it.

We refer to Fig. 3 which shows a simple outline such as might form the silhouette observed by the camera 5.

In the 'teach' mode the computer may record parameters such as:

Weight (an important feature of the invention)

1. Number of holes.
2. Area.
3. Perimeter lenght a) including holes
b) excluding holes
4. Shape factor (=square of perimeter area)

For the following measurements the centre of gravity of the area (point A) and the centre of gravity of the perimeter (point B) are calculated. The centre of gravity of the perimeter excluding holes (point C) can also be calculated.

5. Maximum length to perimeter from point A.
6. Minimum length to perimeter from point A.
7. Maximum length to perimeter from point B.
8. Minimum length to perimeter from point B.
9. First moment of area about point A.
10. Second moment of area about point A.
11. First moment of perimeter about point B.
12. Second moment of perimeter about point B.
13. Minimum length to perimeter excluding holes from point A.
14. Minimum length to perimeter excluding holes from point B.
15. Maximum length to perimeter from point C.
16. Minimum length to perimeter including holes, from point C.
17. Minimum length to perimeter, excluding holes, from point C.

The above dimensions require the identification of four points on an article with no holes and nine points an article containing holes when viewed in silhouette. Maximum dimensions can also be measured from these points instead of the point defined above to give a further possible maximum nine dimensions to give a total of 21 readings.

If the article contains holes when viewed in silhouette, the area, perimeter, shape factor, maximum and minimum length and the first and second moments of the hole area and perimeter can also be calculated. If all the holes are dealt with as one feature this would produce a further eleven readings giving a total of 32 possible measurements. For an article with a hole, the hole itself can be treated as a silhouette and parameters measured on just this hole.

Also the facility for measuring the angle between any two lines defined on the article by the maximum or minimum readings may be included. Even on a simple article without holes this gives a total of six angles that could be determined.

Clearly to measure all the angles and parameters that could be measured is impractical and unnecesary. Preferably the angle between the maximum and minimum dimensions detected on the perimeter—including any holes present—from the centre of gravity could be measured in addition to some other limiting measurement or measurements.

From this large amount of information the computer is instructed to select the minimum number of parameters necessary to identify each article positively, and this may vary from article to article. An important feature is the inclusion of fail-safe selection procedures for the parameters to ensure that no two articles have recognition parameters including coefficients or variation which take into account variations in shape of unfinished articles which could possibly result in one article being incorrectly identified as another. These selected parameters are then the only ones calculated by the computer when it inspects an article, the weight being a decisive limiting parameter in each case.

Complete finished articles may be presented as ideals to the recognition system to identify the lower limits of excess metal and weight. Manual instruction may also be given.

If required rejected articles may be repositioned and reintroduced for the purpose of recognition.

The final orientation of a component for positioning ready to be picked up for subsequent treatment could be measured by measuring the angle between a specified line of the system, for example line A to B and line A to the minimum dimension, or if the component has a hole, from the centre of gravity of the hole to the centre of gravity of the whole silhouette provides another useful line.

The essence of the invention may be summarised as recognition means capable of identifying each of a number of different kinds of article which may be unfinished and of varying shape and using its recognition to re-orientate and re-position and to turn over an object so that it lies at a precisely known position and at a known orientation, the method of recognition being by a combination of silhouette parameters which are compared with parameters already learnt by the computer to be acceptable for a particular category of article, and the parameters preferably include the weight of the article.

As compared with known systems the invention includes a weight and silhouette inspecting device as means of examining an article to determine whether or not the article lies within an acceptable range of variation for any particular class of article. The system is capable of identifying an article as belonging to a category or class despite significant variations in the parameters it has to monitor.

CLAIMS

1. A system for identifying and orientating articles presented to it at random in succession comprising means for illuminating the article to present an image, from which a number of dimensional parameters are obtained, these paramters, being analysed in a computer and compared with the figures for known classes of articles, and including means for tilting the article to different configurations if necessary and finally means, controlled by the computer, for presenting the article in a predetermined configuration and orientation for subsequent handling.

2. A system according to claim 1 including means for weighing the article to produce a weight parameter which is included in the said analysis of parameters.

3. A system according to claim 1 or claim 2 in which the illuminating means comprise an infra-red or ultra-violet source.

4. A system according to any one of claims 1 to 3 in which the image is obtained by a digital camera.

5. A system according to claim 4 including means for centralising the article into a predetermined position in a field of view before the image is obtained by the camera.

6. A system according to any one of claims 1 to 5 in which the orientating means include a table which is rotatable about a central vertical axis.

7. A system according to claim 6 in which the illuminating means illuminate the article from below while it is on the table and the image is formed above the article.

8. A system according to claim 6 or claim 7 as dependent upon claim 2 in which the means by which the weight parameter is obtained is incorporated in the table.

9. A system according to any one of claims 1 to 8 in which the tilting means comprise a step of adjustable height over which the article is pushed, so as to fall by gravity into a new configuration.

10. A system according to claim 9 including means for setting the height of the step in accordance with the class of article and its configuration at the time.

11. A system according to any one of claims 1 to 10 in which the dimensional parameters by which the article is recognised include the area of the silhouette, its perimeter, the presence of any holes, and the relative positions of the centres of its area and its perimeter.

12. A system according to claim 11 in which the dimensional parameters by which the article is recognised include the minimum and/or maximum lengths from one or more of the said centres to its perimeter.

13. A system according to claim 11 or claim 12 in which the dimensional parameters by which the article is recognised include the first and/or second moments of area about one or more of the said centres.

14. A system for identifying and orientating articles presented to it at random in succession, substantially as described with reference to the accompanying drawings.

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